



U.S. Department
of Transportation
**Federal Aviation
Administration**

Memorandum

Subject: **INFORMATION**: Public Statement Number PS-
ACE100-2001-004 on Guidance for Reviewing
Certification Plans to Address Human Factors for
Certification of Part 23 Small Airplanes

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From: Manager, Small Airplane Directorate, ACE-100

Reply to
Attn. of:

To: See Distribution

Summary

The purpose of this memorandum is to clarify Federal Aviation Administration (FAA) certification policy on human factors. Recent requests for guidance on the content and structure of human factors certification plans (HFCP) for part 23 airplanes has prompted this policy statement. This policy statement provides guidance to FAA certification teams for review of an applicant's HFCP or the human factors (HF) components of a general certification plan when one is submitted as part of a type certification (TC), supplemental type certification (STC), or amended type certification (ATC) project. FAA certification teams are encouraged to use this policy in reviewing certification plans. The application of this guidance will ensure that human factors issues are adequately considered and addressed throughout the certification program. This plan advocates early FAA involvement during the development process of a new product and the establishment of a cooperative working relationship between the FAA and the applicant. Early FAA involvement and an effective working relationship between the FAA and the applicant will greatly aid in the timely identification and resolution of HF related issues.

Policy

TABLE OF CONTENTS

Background	3
Objective of this Policy	4
General Statement of Policy	5
1. Introduction	5
2. System Description.....	5
3. Concept of Operation Considerations	7
4. Certification Requirements	8
5. Methods of Compliance	10
6. System Safety Assessment	10
7. Certification Documentation	11
8. Certification Schedule	11
9. Use of Designees and Identification of Individual DER/DAR.....	12
 Appendix A Partial List of Part 23 Regulations	
Related to Human Factors	14
Appendix B Related Documents	33
Appendix C Example of Methods of Compliance	37
Appendix D Sample Human Factors Compliance Matrix	40
Appendix E Checklist for Reviewing Human Factors Certification Plans ...	41
Appendix F Glossary and Acronyms from RTCA/DO-229C	42

BACKGROUND

General aviation fatalities (part 91 operations) occur at higher rates than part 121 and part 135 operations. Many of these accidents are attributed to human error. In order to improve safety, human performance issues need to be addressed by focusing on a human centered design process.

Recent aviation safety reports (see Figure 1 below and the 1999 Nall Report) (available from the Airplane Owners and Pilots Association, <http://www.aopa.org>) that discuss accidents, incidents, and other safety related events underscore the importance of addressing issues related to human factors and flight crew error. The most effective time to address human performance is early in the development phase of the new product.

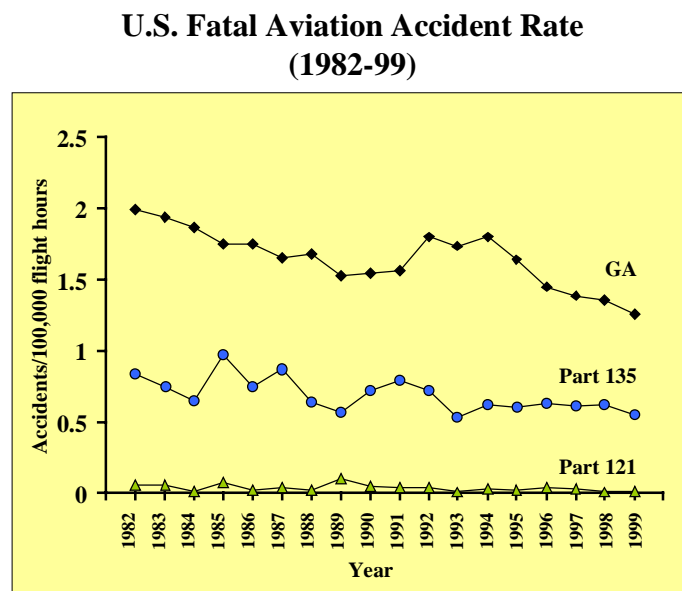


FIGURE 1

Some applicants have developed and submitted a “Human Factors Certification Plan” (HFCP) to establish and formalize the methods that will be used to identify and address human factors (HF) issues. This approach is effective in that it can provide an early estimate of the level of human factors engineering effort that will be required for a TC, STC, or ATC project.

The human factors guidance contained in this policy is consistent with the goals identified in the FAA Industry Guide to Product Certification (Jan 99) and the FAA Industry Guide to Avionics Approvals (Apr 01). The applicant and the FAA can use an HFCP based on this policy to establish an early and formal written agreement on the certification basis, the methods of compliance, and the schedules for completing the certification project.

An HFCP can also be used informally to establish discussions of HF topics and schedule meetings to resolve any issues. This approach has helped FAA certification teams address issues early in the certification process. These early discussions can reduce the applicant’s time and cost to obtain certification. As an alternative to developing a stand-alone HFCP, an applicant can address the HF issues as part of their general certification plan. Regardless of whether it is a stand-alone plan or not, the trend is that applicants have been providing some specific information about their plans to address HF issues in the certification project.

Increasing numbers of applicants have asked for assistance from the FAA in developing an HFCP. Given this trend, the Small Airplane Directorate has developed this policy to assist FAA certification team members (which may include designees and delegated organizations) in working with applicants who are attempting to develop an HFCP, as well as in reviewing these plans after they have been submitted.

OBJECTIVE OF THIS POLICY

This policy’s objective is to provide guidance to FAA certification project teams for reviewing the applicant’s HFCP or the HF components of a general certification plan during a certification project for small airplanes. The policy is intended for use by all project team members, who may include the following:

- aircraft evaluation group inspectors,
- avionics engineers,
- project managers,
- flight test pilots and engineers,
- HF specialists,
- propulsion engineers, and
- systems engineers.

While this policy is focused on providing guidance to the FAA project team, the applicant may also find it useful. If the applicant develops a certification plan, this policy statement can be used as a basis for the development of the structure and content of an HFCP.

GENERAL STATEMENT OF POLICY

Guidance for Reviewing Certification Plans to Address Human Factors for Certification of Small Airplanes

The guidance provided in the following sections should help the certification project team review an applicant's HFCP. It is organized into nine sections. These sections are consistent with information described in FAA Advisory Circular (AC) 21-40, "Application Guide for obtaining a Supplemental Type Certificate." This information is also consistent with more recent guidance published in the FAA/Industry guide to product certification. In addition, the FAA/Industry guide to avionics approvals contains more specific discussion on how to address human factors design of avionics equipment. Both of these documents can be found on GAMA web site www.generalaviation.org under the topic of certification and technical publications.

The six appendices included in this document provide additional information that will be helpful in the evaluation of an HFCP. Appendix A provides a discussion of human factors related regulations. Appendix A also includes examples of human factors compliance criteria that can be used in the HFCP. Appendix B is a listing of related documents that provide general certification process guidance. It also lists publications that provide specific guidance applicable to small airplanes. An example of such guidance referenced in this Appendix is GAMA Publication No.10. (Recommended Practices and Guidelines for Part 23 Cockpit/Flight Deck Design). This publication is non-regulatory, but may provide additional information that is useful in the review of an HFCP and methods of compliance. Appendix C provides examples of methods of compliance. Appendix D contains an example of a Human Factors Compliance Matrix. Appendix E provides a checklist for reviewing human factors certification plans. Appendix F contains a glossary of acronyms from RTCA/DO-229C

The HFCP or the human factors components of a general certification plan should contain the elements as outlined in the following information.

1. Introduction

This section of the Certification Plan should provide a short overview of the certification project, the certification program in general, and the purpose of the HFCP.

2. System Description

This section of the Certification Plan should contain a comprehensive description of the cockpit or flight deck system, or component being presented as part of a certification project. The applicant can use this section to ensure that the project certification team and the applicant have a common understanding of the design, function, and operation of the system.

The HFCP should describe any new or unique features or functions and discuss how the flight crew is expected to use them. Specifically, the following topic areas may be included:

2.a. Intended Function.

This section should describe the intended functions of the major flight crew interfaces. For each, the HFCEP should identify the following items, as appropriate, focusing on new or unique features that affect the crew interface or the allocation of tasks between the pilot(s) and the airplane systems:

- The intended function of the system from the pilots' perspective.
- The role of the pilot relative to the system.
- The degree of integration or independence with other flight deck equipment.
- The novelty of the system.
- The assumed airplane capabilities (for example, communication, navigation, and surveillance).
- The criticality of the system and alerting mechanism.

2.b. Cockpit or Flight Deck Layout.

Drawings of the cockpit or flight deck layout, even if they are only preliminary, can be beneficial for providing an understanding of the intended overall cockpit or flight deck arrangement (controls, displays, sample display screens, seating, stowage, and so forth). Encourage the applicant to provide scheduled updates to the drawings. These updates will help the Certification Team stay current as the design matures. Special attention should be given to any of the following that are novel or unique.

- Arrangements of the controls, displays or other cockpit or flight deck features or equipment.
- Controls, such as cursor control devices, or new applications of existing control technology.
- Content and format of the pilot interface on the display as generated by the systems software.
- Display hardware technology.
- Screen usage, alerting mechanisms, and mode annunciation.

For the items listed above, sketches of the crew interfaces for the specific systems can be helpful in providing an early understanding of the features that may have certification issues.

2.c Underlying Principles for Automation Logic.

The design of the system's automated functions should be defined early in the process. The automation features should follow a design philosophy that supports the intended operational use regarding the system behavior; modes of operation; and pilot interface with controls, displays and alerts. For designs that involve significant automation, the way automation operates and communicates that operation to the pilot can have significant effects on the crew interface. The HFCEP should identify any human factors issues related to the following:

- Principles underlying mode transition.
- Mode annunciation scheme.
- Automation engagement or disengagement principles.
- Level of automation.
- Preliminary logic diagrams, complexity of the logic, if available.

3. Concept of Operation Considerations

This section of the Certification Plan should describe the general characteristics of the intended user population, operating environment, system operating procedures, and any proposed training that may be required. An FAA airplane evaluation group (AEG) inspector should be involved in the review of this section of the HFCP.

3a. Pilot Characteristics.

The HFCP should contain a description of the characteristics of the pilot group the manufacturer expects will be using the cockpit or flight deck. This description should include assumptions about the following:

- Part 91 pilots (including those who participate in personnel flying and flying as part of corporate and fractional ownership. Also consider their flying experience, ratings, flight hours in terms of minimums and average.)
- Part 135 pilots (air taxi and commuter operations)
- Experience with similar equipment (other equipment that is typically used by GA pilots)
-

3.b. Operational Considerations.

The HFCP should describe the type of flight operations and expected operating regulations in which the product was designed to support and operate. As a minimum, the following should be considered and discussed if applicable:

1. Parts 91, and 135
2. VFR or IFR, or both
3. Types of Approaches (Cat I, II, III)
4. Day or Night
5. Flight into Known Icing Conditions
6. High Altitude Operations
7. Airport Types and Conditions (unimproved runways, runway length, snow or ice, etc.)

3.c. System Operation Procedures.

(Also see 14 CFR part 23, § 23.1585.) The HFCP should include a summary of any expected additions or changes to equipment operation procedures, emergency procedures and flight operations (that is, setting up the GPS for an IFR approach). It is useful to describe changes to the procedures as the design of the system and use of procedures are

interrelated. The HFCP should also discuss potential failure modes and alternate or backup procedures. This section may include the following:

- Quick Reference Card or Handbook, or both
- Equipment Operation Manual
- Checklist (including automated, if applicable)
- Emergency or Abnormal procedures
- Methods to reduce the occurrence and consequences of crew error.
- Methods to preclude inadvertent installation of field loadable software that is not compatible with the existing system configuration
- Methods to preclude the activation of maintenance diagnostic functions during flight

3.d. Training requirements.

The HFCP should describe training that may be required to properly operate the new system. The HFCP should also discuss the training assumptions that were made during system development (for example, user will self train using owners manual, user will attend a company sponsored training class, and so forth). The applicant should include a discussion of the methods that will be used to provide this training, the estimated time it will require, and whether the user will have to demonstrate a level of proficiency. In addition, the HFCP should discuss any currency requirements. Currency considerations could take the form of the following:

1. Periodic operations (i.e., operate the system every 30 days)
2. Recurring training (i.e., ground or flight training, manual review every 6 months)
3. Periodic Demonstrations of Proficiency (i.e., practical test every 6 months)

4. Certification Requirements

In this section of the HFCP, the HFCP should identify all HF related regulations that apply to the installation of the system or component being certified. The applicant may choose to incorporate this information in the overall certification plan. However, regardless of how the regulations are identified, the HFCP should indicate how compliance to those regulations will be accomplished. As part of this section, the applicant may include the compliance checklist.

Many of the regulations that have HF implications are also within the purview of other engineering disciplines; therefore, demonstration of compliance with 14 CFR parts may include more than one engineering discipline. For regulations with HF implications, the HFCP should identify which discipline or individual will be responsible for demonstrating compliance to these regulations.

The following is a partial listing of 14 CFR parts and sections that are related to HF certification. The HFCP should identify all the applicable HF related regulations, including the applicable regulations from this list, and address them in the HFCP or the appropriate section of the overall certification plan.

We have chosen not to address all of these documents for the following reasons:

1. The requirements are clearly stated in the rule and no additional information is needed.
2. There is an AC or other recognized guidance that already addresses this issue and there is no reason to repeat the information in this document.
3. Some rules are system specific, e.g., fuel, electrical, or oxygen, etc., and are typically addressed by other disciplines within the FAA (i.e., propulsion, electrical, etc.)
4. Some regulations fall under the sole purview of the flight test pilot community and have not been problematic from a human factors perspective.

SUBPART B—FLIGHT

MISCELLANEOUS FLIGHT REQUIREMENTS

23.251 Vibration and buffeting

SUBPART D—DESIGN AND CONSTRUCTION

CONTROL SYSTEMS

23.671(a), and (b) General

23.672(a), and (b) Stability augmentation and automatic and power-operated systems

23.677(a) Trim systems

23.679(a) Control system locks

PERSONNEL AND CARGO ACCOMMODATIONS

23.771(a) Pilot compartment

23.773(a)(1), and (a)(2) Pilot compartment view

23.777(a), (b), and (e) Cockpit controls

23.785(e) Seats, berths, litters, safety belts, and shoulder harnesses

SUBPART F—EQUIPMENT

GENERAL

23.1301(a) Function and installation

23.1309 (b)(3) Equipment, systems and installations

INSTRUMENTS: INSTALLATION

23.1311 Electronic display instrument systems

23.1321(a), and (e) Arrangement and visibility

23.1322(a), (b), (c), (d), and (e) Warning, caution, and advisory lights

ELECTRICAL SYSTEMS AND EQUIPMENT

23.1357(d) Circuit protective devices

23.1367(c), and (d) Switches

LIGHTS

23.1381 (a), (b) Instrument lights

MISCELLANEOUS EQUIPMENT

23.1431(c) Electronic equipment

SUBPART G—OPERATING LIMITATIONS AND INFORMATION

23.1523(a), (b), and (c) Minimum flight crew

MARKINGS AND PLACARDS

23.1555 Control markings

Appendix A lists these regulations and discusses the relevant human factors issues that may affect the chosen methods of compliance.

5. Methods of Compliance

The HFCP should contain the applicant's plan for showing compliance. An applicant should explain the methods that will be used to demonstrate compliance with relevant regulations. The HFCP should describe these methods in sufficient detail to allow the FAA certification team to evaluate the appropriateness and adequacy of the proposed methods of compliance. It is important that the proposed methods of compliance contain enough fidelity to identify HF issues early in the program to avoid certification schedule delays. The FAA and applicant should review and discuss the proposed methods of compliance early in the certification program to identify any potential HF certification issues.

It would be beneficial for the applicant and certification team to have several coordination meetings during the certification program to review the compliance checklist and the associated test plans as they are developed. This will help all parties reach an understanding on how the tests, demonstrations, and other data-gathering efforts are adequate to find compliance.

Appendix D includes examples of compliance methods and related discussion. Appendix E contains a checklist for reviewing the HFCP.

6. System Safety Assessments

Typically, applicants prepare system safety assessments in accordance with AC 23.1309. These may include a Functional Hazard Assessment (FHA), Failure Modes and Effects Analysis (FMEA), Fault Tree Analysis, and so forth. For each assessment planned, the HFCP should describe how they will address any HF elements (such as crew responses to

failure conditions) and their assumptions about crew behavior. All certification team members should review these assumptions to ensure the flightcrew can compensate for all expected failures. These HF considerations can be documented in the individual system safety assessments, or the applicant may elect to describe them in the HFCP, with references to the associated system safety assessments.

7. Certification Documentation

The HFCP should identify the types of documentation that will be submitted to show compliance or otherwise record the certification program progress. This section may list the specific document (test report number, analysis report number, and so forth) that will be used to support compliance with the subject regulation. The document may also be listed in the compliance matrix (See Appendix D example).

8. Certification Schedule

This section of an HFCP should include the human factors certification activities that relate to the major milestones of the certification program. If this information is provided in the overall certification plan, it need not be repeated in the HFCP. The following are some suggested topics that may be addressed in this section:

8a. HFCP Certification Plan Submittals:

The Certification Team should expect periodic HFCP updates as the certification program progresses. The applicant should be encouraged to send the first HFCP as soon as possible after the start of the program. The FAA certification team should review the preliminary draft and inform the applicant that the draft preliminary information is adequate and appropriate. This information should be updated and finalized in a timely manner as documented in the schedule and agreed to jointly by the FAA and the applicant.

8.b. Cockpit or Flight Deck Reviews, Early Prototype Reviews, Simulator Reviews, and Flight Test Demonstrations:

The HFCP may include planned design reviews. Even in cases where the reviews are not directly associated with finding compliance, they can be very helpful in the following ways:

- Providing the Certification Team with an accurate and early understanding of the crew interface tradeoffs and design proposals.
- Allow the certification team to provide the applicant early feedback on any potential certification issues.
- Support cooperative teaming between the applicant and the certification team, in a manner consistent with the Certification Process Improvement initiative.

8c. Coordination Meetings:

Coordination meetings with other certification authorities, or meetings with other FAA Aircraft Certification Offices on components of the same certification project or related projects, should be documented in the schedule.

The Certification Team can use the information in the schedule to determine if sufficient coordination and resources adequately address the HF issues for the certification program.

9. Use of Designees and Identification of Individual Designated Engineering Representative (DER)

Currently, compliance to the HF related regulations cited in this policy are under the purview of disciplines other than human factors engineers. For many of these regulations, flight test Designated Engineering Representatives (DER's) are responsible for showing and finding compliance with these regulations. As such, the HFCP should identify whoever is responsible for finding compliance with these regulations.

Effect of Policy

The general policy stated in this document does not constitute a new regulation and the FAA would not apply or rely upon it as a regulation. The FAA Aircraft Certification Offices (ACO) that certificate normal, utility, acrobatic, and commuter category airplanes should attempt to follow this policy when applicable to the specific project. Whenever an applicant's proposed method of compliance is outside this established policy, it must be coordinated with the policy issuing office as a standard practice.

Applicants should expect that the certificating officials will consider this information when making findings of compliance relevant to new certificate actions. Also, as with all advisory material, this policy statement identifies one means, but not the only means, of compliance.

The general policy that is stated in this document is intended to provide internal guidance to FAA certification teams. The purpose of the guidance is to enable them to conduct an effective review of the applicant's HFCP (or HF components of a general certification plan) when one is submitted as part of a TC, STC, or ATC project. The general policy stated in this document is not intended to establish a binding norm; it does not constitute a new regulation, and the FAA would neither apply nor rely upon it as a regulation. The FAA Aircraft Certification Offices, and authorized designees, who approve the design of small airplanes and systems installed in the cockpit should attempt to follow this policy. Also, information contained in this policy may also be useful to those offices and individuals responsible for field approvals via form 337. Although the application of this policy is not mandatory, FAA offices should utilize the guidance in this document to ensure that human factors are adequately and consistently addressed during certification. This policy was not written to determine who should be responsible for certification compliance findings for any particular project or program. In determining compliance, each FAA certification office has the discretion to apply part or all of these guidelines as deemed appropriate.

s/ James E. Jackson
for

Michael Gallagher
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Aircraft Certification Service

APPENDIX A

Partial List of Part 23 Regulations Related to Human Factors

For the purposes of brevity, some of the regulations have not been restated in their entirety. However, the regulation part associated with HF issues has been reproduced. For all compliance-related documents, the HFCP should use the exact wording of the regulation.

This list of regulations contained in this Appendix is not intended to include all regulations associated with HF and flightcrew interfaces. Also, several of the regulations are written in general terms, in these cases subjective data are often utilized to establish compliance. The intent of the information in this section is to assist in understanding the human factors implications of the more frequently referenced regulations. It also provides examples of how to demonstrate compliance to these regulations. This information should help the reviewer determine if the applicant has adequately addressed the HF related requirements for the more commonly referenced regulations.

Due to the subjective nature of many of the HF aspects of the regulations, the FAA encourages the applicant to carefully consider and thoroughly describe the means that will be used to demonstrate compliance with each regulation. The applicant may choose to provide the detailed description of the means of compliance in subsequent submitted test plans. The information contained in the **Discussion** paragraph for each regulation contained in this Appendix should be used to assess the appropriateness and adequacy of the applicant's chosen methods. The FAA and the applicant should meet to discuss and reach agreement as to the acceptability of the proposed techniques prior to the beginning of collection of compliance demonstration data. Compliance may be demonstrated through similarity and minimal testing for simple and straightforward applications that have little impact on pilot workload, situation awareness, tasking or performance.

More complex, integrated designs may require pilot evaluation under actual anticipated flight conditions. For these tests, use a representative pilot population to ensure that future system users can safely and effectively operate the system in the intended operational environment. The test program should include sufficient simulation (see Appendix C) and flight testing to ensure:

1. Reasonable training times and learning curves.
2. Acceptable interpretation and operation error rates equivalent to or less than previously certified comparable systems.
3. The intended user (pilot) of the system does not require any exceptional skill or strength to operate the system.
4. Proper integration and compatibility with other controls or displays, or both, and other equipment in the cockpit.
5. Typically all airplane systems are designed to minimize failures. However, if a system failure occurs, the pilot should be able to safely continue to operate the airplane. It is not

acceptable for the pilot to be given misleading information in the event of a malfunction. The FAA should also encourage the applicant to conduct early analyses and evaluations of new systems to facilitate timely identification and resolution of HF related certification issues.

The following is a partial listing of the HF related regulations and associated **Discussion** of each of those regulations along with considerations for demonstration of compliance.

§ 23.251 Vibration and buffeting

There must be no buffeting in any normal flight condition severe enough to interfere with the satisfactory control of the airplane or cause excessive fatigue to the flight crew.

Discussion: A major HF consideration for this regulation is the vibration induced fatigue that may result from the high level of concentration needed to read the instruments and operate controls. When determining compliance, careful consideration should be given to the frequencies and magnitudes of the vibration, and the duration of exposure to these circumstances under normal conditions. Tasks that may be particularly affected by vibration include the capability to read displayed information and access or operate controls. Evaluations should be conducted to verify that any potential buffeting that could occur during normal flight conditions does not interfere with the pilot's capability to perform these tasks and satisfactorily control the airplane. If it is possible for the pilot to be exposed to the vibrations for extended periods, then evaluations should be made under worst case duration conditions to determine the effect on pilot fatigue. Consideration should be also given to a related regulation – 14 CFR part 23, § 23.771(a). This rule addresses unreasonable concentration and fatigue from a pilot compartment and equipment design and layout perspective.

§ 23.671 Controls Systems, General

(a) Each control must operate easily, smoothly, and positively enough to allow proper performance of its functions.

(b) Controls must be arranged and identified to provide for convenience in operation and to prevent the possibility of confusion and subsequent inadvertent operation.

Discussion: This is a general rule for controls that can be applied to any system with a control function, including flight controls and avionics equipment. The physical characteristics of a control, such as size, shape, and method of operation can affect its ease of use. These characteristics can also impact the adequacy of control feedback and can aid in preventing inadvertent control operation. Also, control arrangement, that is its relative location in the cockpit, functional association to nearby controls (functional grouping), and its distance (spacing) from nearby controls, can affect the identification and usability of a control. These factors should be considered when evaluating compliance to these regulations.

Consideration should be given to the potential for errors associated with control identification and arrangement, and the possible consequences of such errors. The applicant

may choose to conduct an error analysis to determine the consequences of inadvertent operation errors on system operation and safety. The results of such analysis can greatly aid in the identification and understanding of potential operation errors. This data should be supported by evaluations.

As a minimum, evaluations should be conducted in a representative cockpit that accurately portrays the geometry and layout of the airplane or system. The applicant may choose to use physical mock-ups for preliminary evaluations. Simulators, if available, create a more powerful evaluation environment. The use of simulators allows evaluations to be conducted using representative flight scenarios that provide more realistic control use and operation sequences. Simulator evaluations may reduce flight test time through early identification and resolution of any problems that may occur prior to actual flight test.

Each control should be examined and operated to evaluate the ease of identification and use. The control should also be evaluated for the potential for inadvertent activation. Attention should also be given to potential interference from adjacent controls. If there is a potential for inadvertent activation, the consequences of those errors need to be examined in terms of the effect on system operation and safety.

Training has often been used to mitigate the potential for inadvertent operation of controls. Caution should be exercised whenever training is proposed to address a potential inadvertent operation error concern. The use of training to address potential inadvertent operation issues has not been shown to be consistently successful.

In the past, failure to properly address inadvertent operation has resulted in design induced pilot errors. There have been accidents and incidents associated with inadvertent operation of controls. These mistakes can become dangerous if the error is made during the more critical phases of flight. For example, if a pilot is unaware that he has activated the autopilot during approach, it could result in an accident.

The certification team and the applicant should refer to the design-related reference materials contained in Appendix B. Appendix B also contains useful guidance material that describes how to avoid these potential problems.

§ 23.672(a) Stability augmentation and automatic and power operated systems

A warning, which is clearly distinguishable to the pilot, without requiring the pilot's attention, must be provided for any failure in automatic or power-operated systems that could result in an unsafe condition if the pilot was not aware of the failure.

Discussion: An important human factors issue is to provide a warning signal that cannot be confused with other cockpit alerts. If an audio signal is used, the pilot must be able to discriminate it from all other cockpit audio alerts. If several tones are used in the cockpit, it can complicate the pilot's tasks. It is important that auditory alerts be used judiciously. The number of auditory alarms should be kept to the minimum necessary to provide the desired result. Too many alerts can become annoying, increasing pilot workload and detract from a pilot's primary flight responsibilities. Spoken alerts can have advantages over other forms of auditory warnings since they convey specific information without the pilot having to

interpret a tone or revert to a visual display to determine the exact failure. Regardless of the method chosen to present auditory alerts, they should be evaluated to determine that they are readily detectable, easily heard under all ambient noise conditions and quickly and correctly interpreted.

Since the general aviation pilot population includes many individuals who have hearing deficiencies, special consideration needs to be given to this situation when conducting evaluations of auditory warning systems. Ensure that the alerting tone or voice message is of sufficient intensity (loudness) that it clearly stands out against all normal background noise.

Evaluations should be conducted in the aircraft during both ground and flight operations with varying levels of background noise. Applications that employ voice technology should meet these same criteria. Analysis, simulation or flight test should be conducted to show that the system will not produce nuisance alerts when the airplane is conducting normal flight operations.

§ 23.672(b)

The design of the system must permit initial counteraction of failures without requiring exceptional pilot skill or strength.

Discussion. Determination of exceptional pilot skill or strength is subjective. When evaluating for "exceptional pilot skill," evaluators should consider the complexity of the task in terms of the performance requirement (level of accuracy or precision), the number of steps, training requirements, memory load, checklist use, and time-to-perform. These evaluations are normally done by the test pilots involved in the program. For any new or novel designs, the guidance provided in the beginning of this appendix concerning multiple pilot evaluations should be followed. For "exceptional pilot strength," it is also important that evaluations be conducted considering the minimum strength capabilities of the pilot. Guidance that may be useful to applicants to aid in determining strength considerations is found in the strength study in item 9 of Appendix B. This study provides several examples of maximum force exertion from various locations of controls in the cockpit; however, there are always unique situations that can arise during the design of a new or modified cockpit. When new or unique situations arise, evaluations should be conducted early on to ensure that the strength required to activate the control does not fall outside the limitations of the pilot population. The FAA will make the final determination of compliance for this requirement.

§ 23.677(a) *Trim systems*

There must be a means to indicate to the pilot the position of the trim device with respect to both range of adjustment and, in the case of lateral and directional trim, the neutral position. This means must be visible to the pilot and must be located and designed to prevent confusion. The pitch trim indicator must be clearly marked with a position or range within which has been demonstrated that takeoff is safe for all center of gravity positions and each flap position approved for takeoff.

Discussion. Human factors issues have been associated with the airplane trim wheel location. In some instances, trim wheels have been placed in positions that are difficult to see and require the pilot to assume an awkward body position to read and operate. The inability to see the trim wheel position can create the potential for an accident. Assuming an awkward body position to see or operate the trim wheel can result in inadvertent flight control inputs. It can also result in additional time spent heads down and cause the pilot to not see traffic or other situations occurring outside of the cockpit. The HFCP should indicate that the applicant performed early analysis to determine if visual and physical access to the trim wheel is adequate. Evaluations should then be conducted to ensure the proposed design accommodates various size pilots, as defined by the applicant, in order to determine if they can readily see and adequately operate the trim mechanism without confusion or undue concentration.

§ 23.679 Control system locks

If there is a device to lock the control system

(a) There must be a means to—

- (1) Give unmistakable warning to the pilot when the lock is engaged; or
 - (2) Automatically disengage the device when the pilot operates the primary flight controls in a normal manner.
- (b) The device must be installed to limit the operation of the airplane so that, when the device is engaged, the pilot receives unmistakable warning at the start of the takeoff.
- (c) The device must have a means to preclude the possibility of it becoming inadvertently engaged in flight.

Discussion. A number of accidents have occurred because pilots have tried to take off with either the manufacturers control lock or a substitute device in place. Although normal preflight procedures should prevent this situation from happening, accidents continue to happen. There are a couple of issues that can cause this problem. One has to do with the obviousness of the "unmistakable" warning and the second is the use of unapproved devices to secure the control (for example, a common bolt inserted through the control column hole). Various approaches and devices have been developed to make it "very" apparent that the control is locked. When evaluating a control lock system several factors should be considered in finding compliance with the regulation.

- a. The warning should be easily discernable during both day and night operations. Color, location, shape, and accessibility of the device, ease of removal by a seated pilot, and legibility of any placards, etc., should be considered.
- b. The system operation should be obvious. It should only be possible to install the lock such that the warning placard is properly displayed.

c. When engaged, the lock should, by design, limit the operation of the airplane so that the pilot receives unmistakable warning in the cockpit before or at the start of takeoff by an effective means such as:

- (1) preventing the application of sufficient engine power to attempt takeoff;
- (2) displacement of primary pilot controls, such as the control wheel full forward; or
- (3) an aural warning device that cannot be disengaged.
- (4) Preventing the engine (s) from being started by blocking key insertion or by covering the starter switch.

d. For airplanes with separate locks for throttle and control column, where one lock (e.g., throttle) can be removed independently of the other, each lock should independently meet the criteria in item c above.

§ 23.771(a) Pilot compartment

Each pilot compartment and its equipment must allow the minimum flightcrew to perform their duties without unreasonable concentration or fatigue.

Discussion: The HFCEP should identify the aspects of the flightcrew interface that might require significant or sustained mental or physical effort that may lead to fatigue. There are many factors that can affect fatigue, such as noise, vibration, seat comfort, poorly designed controls or displays and excessive control forces. Methods of compliance should focus on evaluation procedures that examine potential concentration demands and sources of fatigue for the flightcrew. Comparisons to previously certified designs may be used to determine the acceptability of a system. Some issues that can contribute to pilot fatigue are as follows:

The ease of identification, accessibility, and usability of cockpit controls can affect the level of pilot concentration. Evaluations should be conducted to ensure all cockpit controls are easy to identify, access, and operate as required in flight.

There are a number of factors associated with display design that can ultimately impact concentration and fatigue. Displays that are difficult to read or contain poorly organized information, or lack necessary information, result in greater demands on pilot attention and concentration. Evaluations should be conducted under operationally representative scenarios to assess the effectiveness and usability of the displays.

Noise may also affect crew performance, concentration and fatigue. Evaluations should be conducted to ensure that excessive noise levels are not present, and if noise does exist, to ensure that it does not interfere with crew performance, concentration or cause unacceptable fatigue.

Poorly designed seats have the potential to create fatigue. Seats should be evaluated to determine if they contribute a significant amount of fatigue. These assessments can be conducted using test participants and gathering subjective data. Assessments should be

conducted based upon the average length of flight time that the pilot is expected to remain in the seat for a typical flight for the airplane under evaluation. Subjective comments should be solicited from test participants concerning muscle tension, “hotspots” (areas where harder body contact is experienced), and body soreness or discomfort. Lateral support in the seat pan, and lumbar support in the seat back, have been used to increase seat comfort.

§ 23.773(a)(1) Pilot compartment view (visibility, glare and reflections)

Each pilot compartment must be-

- (1) Arranged with sufficiently extensive, clear, and undistorted view to enable the pilot to safely taxi, takeoff, approach, land and perform any maneuvers within the operating limitations of the airplane.
- (2) Free from glare and reflections that could interfere with the pilot’s vision.

Discussion: § 23.773(a)(1)

1. Sufficient external vision must be provided to enable the pilot to safely fly and control the airplane. The design must provide a level of safety that ensures adequate external vision to “see and avoid” traffic and other obstacles in the environment. In addition, consideration should be given to any optical distortions in the windshield or canopy, especially in the prime viewing areas, which may degrade external viewing.

The HFCEP should define a design eye reference point that will account for the range of expected pilot physical dimensions. The capability to provide an adequate view of the external environment is essential for safe operation. Evaluations should be conducted with individuals that represent a range of different human physical dimensions. Consideration should be given to seat adjustment capability as it accommodates the range of expected pilot physical dimensions. Particular attention should be given to the size and location of aircraft structures that may obstruct the external view. Refer the applicant to documents listed in Appendix B of this policy for additional assistance in addressing this area.

Discussion: § 23.773(a)(2)

2. Glare and reflections.

Vision outside the cockpit must not be compromised by glare or reflections from either internal or external lighting sources. Glare and reflections can significantly degrade display readability and usability, and the capability to see outside the airplane. Unwanted glare and reflections can be produced from sources both inside and outside the cockpit. Mock-ups can be especially useful for early assessments. These preliminary assessments can reduce program risk by identifying potential problem areas early.

High fidelity devices that accurately represent the geometry, layout, and system design characteristics of the actual airplane need to be used to obtain certification credit.

Evaluations should be conducted under all potential lighting conditions to include dawn or dusk conditions with the sun near the horizon, higher sun angles (both in front, behind, and directly overhead the airplane), and during night conditions (both dark night and moonlit conditions). Also evaluate the affect various internal lighting selections and levels have on readability and usability of airplane equipment and systems and the ability to see outside the cockpit.

§ 23.777 Cockpit controls

(a) Each cockpit control must be located and (except where its function is obvious) identified to provide convenient operation and to prevent confusion and inadvertent operation.

Discussion: This regulation is related to § 23.671(b), the important difference is that it addresses the usability of a control from a location and identification perspective. The location of a control can significantly affect:

- (1) the pilot's ability to easily identify the control;
- (2) the ease and convenience of operation of the control;
- (3) confusion as to the control's operation; and
- (4) inadvertent operation of that control.

Several techniques have been used to aid in control identification and use. The size, shape, color, configuration and method of operation have been used to discriminate between controls and aid in control identification. Consideration should be given to these other design related characteristics, relative to the control's location, when evaluating control identification and use. Unless its function and method of operation are obvious, a control must be labeled in accordance with § 23.1555. The suggested analyses and evaluation procedures described for showing compliance with § 23.671 are also applicable and recommended for this regulation.

§ 23.777(b)

The controls must be located and arranged so that the pilot, when seated, has full and unrestricted movement of each control without interference from either his clothing or the cockpit structure.

Discussion: This regulation addresses the capability to operate a control through its full range of motion, considering potential interference from clothing and cockpit structures. It is important that evaluations be conducted using individuals representing a range of potential user physical dimensions and includes tests with users wearing different apparel, such as long sleeved shirts, jackets and gloves. The applicant may use analytical methods, such as computer modeling of the cockpit or flight deck and the pilots, for early problem identification and risk reduction. Regardless of the analytical models used, compliance must be demonstrated in either

a high fidelity mockup that accurately represents the actual airplane or performed in the actual airplane.

§ 23.777(e)

Identical powerplant controls for each engine must be located to prevent confusion as to the engines they control.

Discussion: This topic is also related to the discussion for § 23.671(b). In multi-engine airplanes, there have been accidents caused by instances where the pilot thought he had taken the appropriate corrective action for an engine malfunction, but inadvertently shut down a properly functioning engine. The inability to determine which engine to shut down can be caused by several factors including the lack of association as to which control operates which engine. Other causes include situations where it was difficult to diagnose which engine had the problem, either due to the nature of the malfunction, the adequacy of the warning/alert or adequacy of the engine display system. The evaluation of these controls should include a thorough examination of the control location and mechanization. The physical arrangement of the controls on multi-engine should be consistent with the physical location of the engines on the airplane as far as left to right sequence. They should also be examined in conjunction with their associated displays and warning indications when failures occur. Every effort should be made to provide clear unmistakable indications to prevent these situations from occurring. Also, marking and lighting of the engine controls needs to be clear and distinct to prevent any confusion to the pilot. Compliance testing identified in the HFCP should begin with analysis of initial engineering studies and continue through mock-up, simulator and aircraft ground/flight test evaluations.

§ 23.785(e) *Seats, berths, litters, safety belts, and shoulder harnesses*

The restraint system for each crewmember must allow the crewmember, when seated with the safety belt and shoulder harness fastened, to perform all functions necessary for flight operations.

Discussion: This regulation is related to § 23.777(b); the key differences are that the crewmember must be restrained by the safety belt and shoulder harness, and it only applies to those, "functions necessary for flight operations." The discussion and suggested evaluation procedures for § 23.777(b) are applicable and should be used for finding compliance with this regulation with the exception that evaluations must be conducted with crewmembers seated with safety belts and shoulder harnesses fastened. Additionally, evaluators should only assess the capability to perform functions necessary for flight operations. The HFCP should provide a list of those cockpit functions necessary for flight operations, under normal and abnormal conditions.

§ 23.1301(a) *Function and installation (intended function)*

Each item of installed equipment must—

- (a) Be of a kind and design appropriate to its intended function.

(b) Be labeled according to its identification, function, or operating limitations, or any applicable combination of these factors.

Discussion: This regulation has broad implications and has been used to address a wide range of design and operational considerations. An important aspect of this regulation that can significantly affect the evaluation and finding of compliance is the interpretation of the "intended function" of a system. The interpretation of the systems intended function is typically done by assessing the design, functional capability, and operational use of the system. The applicant will generally provide this information for certification purposes. This information is based upon the applicant's viewpoint of how the system should be operated; however, the system may go beyond what the applicant has envisioned for its use. The FAA should work cooperatively with the applicant so that the "intended function" of a system is accurate, reliable, realistic, and acceptable. Therefore, it is important that the FAA certification team assess the design, functional capability, and use of the system and compare that with the applicant's description of the intended function.

The determination that a system is of a kind and design appropriate to its intended function should be based on performance-based criteria. The ACO should consider the complexity of the system in determining the test requirements. For concerns pertaining to the pilot-vehicle interface, the evaluation should investigate the capability of the pilot to adequately perform related tasks. Performance measures such as time-to-perform, number of inputs, accuracy, comprehension, situational awareness, and perceived workload may be collected to assess compliance. Evaluations should be conducted using operationally representative scenarios. Simulation may be used to verify that properly trained pilots can adequately perform all tasks using the system. Finally, flight tests can be used to investigate specific normal and abnormal operational scenarios.

Item (b) of this rule pertains to proper labeling of cockpit equipment for identification, functionality, and operating limitations. This is usually accomplished by placing a tag or label on the outside of the equipment. For labeling of any associated controls, reference should be made to § 23.1555. This rule specifically addresses control labels and requires that controls be plainly marked as to their functions and methods of operation.

§ 23.1309 Equipment, systems and installations

(b)(3) Warning information must be provided to alert the crew to unsafe system operating conditions and to enable them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors that could create additional hazards.

(b)(4) Compliance with the requirements of this rule may be shown by analysis and, where necessary, by ground, flight, or simulator tests. The analysis must consider—

(iv) The crew warning cues, corrective action required, and the crew's capability of determining results.

Discussion: Section 23.1309 requires that a warning be provided to the crew for any unsafe condition. It also requires that the system be designed to prevent any unwanted actions or operator errors. The applicant may wish to perform analyses of crew procedures in response

to system faults. This can be especially important in cases where the applicant wishes to take certification credit (for example, in a Fault Tree Analysis) for correct pilot response to a system failure. Designs should mitigate the potential for crew error that could contribute to any additional hazards. The applicant should assess the consequences of inappropriate crew response to alerting conditions. Any likely misinterpretations of an alert should be examined to assess its potential for creating additional hazards. Evaluations should also include an assessment of the adequacy of the feedback given to the crew should they make an inappropriate response to a failure. Qualitative evaluations should also be used to supplement and verify analyses of pilot responses. These evaluations should include sufficient testing using a representative population of pilots to ensure acceptable interpretation of responses. Simulation testing, including the use of pilots untrained or unfamiliar with the new design can be especially helpful in demonstrating that the design is not prone to crew interpretation and response errors.

It is important to provide a warning, caution or alert signal that cannot be confused with either other cockpit visual or auditory displays, or both. It is also important that it aids the crew in determining the root cause of the problem and assists them in taking the appropriate corrective action. In addition, there must be immediate and effective feedback of the result(s) of that action. If an audio alert is used, the pilot must be able to discriminate it from all other audio signals. If multiple similar tones are used in the cockpit, it can complicate the pilot's task and increase workload. Thus, it is important that auditory alerts be used judiciously. The use of many alerts can be a nuisance to the pilot, increasing workload and detracting from the pilot's primary responsibilities. The number of auditory alarms should be kept to the minimum necessary to provide the desired result. Voice alerts can have advantages over other forms of auditory warnings in that they can convey specific information without requiring the pilot to interpret a tone or revert to a visual display to determine the cause of the alert. Regardless of the method chosen to present auditory alerts, they should be easily detected and quickly understood in all ambient noise conditions.

§ 23.1311 Electronic display instrument systems

(a)(1) Electronic display indicators must meet the arrangement and visibility of § 23.1321.

(a)(2) Be easily legible under all lighting conditions encountered in the cockpit, including direct sunlight, considering the expected electronic display brightness level at the end of its expected useful life.

(b) The electronic display indicators must be designed so that one display of information essential for continued safe flight and landing will remain available to the crew without need for immediate action by any pilot for continued safe operation, after any single failure or combination of failures.

Discussion: Electronic displays are required to have adequate contrast and brightness to be legible in all ambient lighting environments from bright sunlight to total darkness. The lighting controls must also have an adequate range of adjustment to accommodate these conditions. This requirement is intended to provide readable displays without increasing pilot workload (for example, trying to shield the display to read it).

Evaluations should be conducted under all potential lighting conditions to include dawn or dusk with the sun near the horizon, higher sun angles both in front, behind and directly overhead the airplane, and at night (both dark night and moonlit). One should also evaluate the affect various internal lighting selections and levels have on readability and usability of electronic displays.

The color-coding scheme employed for the airplane display should be evaluated for consistency with those recommended in AC 23.1311-1A. The effective use of color can greatly aid in pilot recognition and interpretation of displayed information. It is important that the use of color in all cockpit applications be consistent across all cockpit displays. The chosen colors should be evaluated to determine if they do in fact enhance the understanding of displayed information. Colors should minimize display interpretation errors. Although the FAA does not mandate color coding conventions for the display of general information on MFD's, there are recommended color-coding guidelines that have worked well in the past that are described in Paragraph 9 of AC 23.1311-1A. It should also be noted that there might be specific color-coding requirements associated with a particular display function based on the type of information presented. For example, if the multifunction display presents terrain information, the color coding requirements associated with AC 23-18 (Installation Terrain Awareness and Warning System) would apply.

This regulation also addresses the need to ensure essential information will be available to the pilot during critical phases of flight without requiring pilot action. For additional information concerning this regulation and methods of showing compliance, see AC 23.1311-1A.

§ 23.1321(a) Arrangement and visibility

Each flight, navigation, and powerplant instrument for use by any required pilot during takeoff, initial climb, final approach, and landing must be located so that the pilot seated at the controls can monitor the airplane's flight path and these instruments with minimum head and eye movement.

Discussion: This regulation requires that primary flight displays be located in the pilot's primary field of view (reference AC 23.1311-1A) and maintain a basic T configuration (reference AC 23-17). Other instruments may be placed outside the pilot's primary field of view. In older part 23 airplanes, powerplant instruments were often located on the right hand side of the cockpit, which often made the instruments difficult to read and caused excessive head or eye movement for the pilot. Today, integrated display technology allows this information to be monitored by the computer and, when needed, integrated onto a display in front of the pilot without the loss of critical flight display parameters. Analysis of the angular offset of a display from the pilot's centerline of vision may be necessary to determine how accessible that display is in a visual scan. Additionally, the visual angle subtended by the display may be used to determine how readable the display will be (apparent display size). Final assessment of the acceptability of the visibility of the instruments will require a geometrically correct mockup or the actual airplane.

§ 23.1321(e)

If a visual indicator is provided to indicate malfunction of an instrument, it must be effective under all probable cockpit lighting conditions.

Discussion: This regulation is closely related to §§ 23.1309(b)(3) and 23.1311(a)(2). The evaluation considerations discussed under those sections are applicable to this regulation as well. Demonstrations and tests intended to show compliance should use production quality hardware and be conducted in a variety of lighting conditions (for example, dark, bright forward field, shafting sunlight). Due to the effect other aircraft electrical systems have on individual systems, compliance tests should be conducted in the airplane, although supporting data from laboratory testing may be submitted to supplement airplane testing.

§ 23.1322 *Warning, caution, and advisory lights*

If warning, caution, or advisory lights are installed in the cockpit, they must, unless otherwise approved by the Administrator, be—

- (a) Red, for warning lights (lights indicating a hazard which may require immediate corrective action);
- (b) Amber, for caution lights (lights indicating the possible need for future corrective action);
- (c) Green for safe operation lights; and
- (d) Any other color, including white, for lights not described in paragraphs (a) through (c) of this section, provided the color differs sufficiently from the colors prescribed in paragraphs (a) through (c) of this section to avoid possible confusion.
- (e) Effective under all probable cockpit lighting conditions.

Discussion: Originally this regulation was written to specifically apply to lights. With the advent of the integrated electronic multifunction display systems, many manufacturers are presenting warnings, cautions and alerts on these MFD's instead of separate annunciation panels. As a consequence, this regulation is being routinely applied to these integrated electronic displays. The use of red and amber for encoding purposes other than warnings and cautions can create confusion on these displays. Red should only be used as a warning annunciation for emergency operational conditions when immediate flight crew recognition and action is required. Amber should only be used for cautionary alerting and when immediate crew awareness is required and subsequent action may be required. White or another unique color should be used for advisory annunciation's of operational conditions that require flight crew awareness and may not require any action. Green should be used for indication of safe operating conditions. See AC 23.1311 for more information.

The HFCEP should describe each warning, caution, and advisory light, including the expected pilot response. Consideration should be given to establishing a well-defined color coding philosophy that is consistently applied across the cockpit. A well-defined and

consistent color philosophy can greatly reduce the likelihood of confusion and interpretation errors.

Evaluations should be conducted in the airplane using actual hardware. Testing should include a variety of lighting conditions. It is important that the selected colors maintain integrity (for example, red looks red, amber looks amber) and discriminability (that is, colors can be distinguished reliably from each other) from all potential viewing angles and under all expected lighting levels.

§ 23.1357(d) Circuit protective devices

If the ability to reset a circuit breaker or replace a fuse is essential to safety during flight, that circuit breaker or fuse must be located and identified so that it can be readily reset or replaced in flight.

Discussion: The applicant may choose to use methods similar to those employed for § 23.777 to demonstrate the ability of the pilot to reach the specific circuit protective device(s). The HFCEP should describe how to evaluate the ability of the pilot to readily identify the device(s), whether they are installed on a circuit breaker panel or controlled using an electronic device (that is, display screen on which the circuit breaker status can be displayed and controlled).

§ 23.1367 Switches

- (c) Each switch must be accessible to the appropriate crewmember
- (d) Each switch must be labeled as to operation and the circuit controlled

Discussion: This regulation is similar to § 23.777(a) and (b), the primary difference is that it applies to electrical switches. The discussion and methods of compliance discussed under that section are applicable to this regulation. The location of cockpit switches should be based upon the criticality of their use (that is, importance, frequency of use, and so forth). Evaluations should be conducted with a wide range of individuals who are representative of the general aviation pilot group, which includes the average flying pilot and not just the highly trained or highly skilled.

§ 23.1381 Instrument lights

The instrument lights must—

- (a) Make each instrument and control easily readable and discernible;
- (b) Be installed so that their direct rays, and rays reflected from the windshield or other surface, are shielded from the pilot's eyes.

Discussion: The primary purpose of cockpit lighting is to allow the crew to quickly see, accurately locate and identify and, if appropriate, interact with displays or controls under both low and high ambient lighting conditions. It is especially important to be able to easily

read all of the illuminated information that appears on the warning/caution/advisories displays. All illuminated information must be easily identifiable, readable and controllable by the pilot under all ambient lighting environments (direct sunlight to total darkness). Cockpit lighting evaluations should ensure that:

- (a) Enough lighting is provided to make the performance of all related tasks easy to accomplish with a high level of speed and accuracy.
- (b) Allow the pilot to be able to recognize and see any hazardous condition or potential hazards quickly, and
- (b) Provide visual comfort.

Glare and flicker can both create visual discomfort. Each lighted component should be individually evaluated for uniform lighting and balance. Each component should also be evaluated for uniformity and balance with all other illuminated instruments. This includes other displays, controls, alerting systems and secondary lighting, all of which should be compatible with each other. Dimming controls should be examined for uniform operation from full bright to off. The dimming ranges should be sufficient to obtain adequate readability throughout the entire operational lighting environment. Consideration should be given to the number of dimming controls in the cockpit. The more dimming controls the pilot must operate the greater the workload and the increased likelihood of confusion and operator error; therefore, dimming controls should be kept to the minimum required. All control markings should be evaluated to ensure they are visible and evenly illuminated during both night and day operations. It should also be noted that font size (variations, e.g., character stroke size, width and height) of the illuminated displays can affect readability and perceived brightness. Variations in font size may create perceived lighting imbalances in the cockpit. (Reference ARP 4103 for recommendations.) Lighting of one control should not interfere with viewing and identification of adjacent controls. Alerting lights must also be evaluated for adequate attention getting value for both day and night operations.

Inspection of the cockpit for glare and reflections should always be considered as part of the evaluation procedure. Evaluations should ensure that glare and reflections do not cause visual discomfort or impair out the window viewing or interfere with other visual tasks. Lighting tests may be conducted in a mockup if available. Aircraft ground and flight tests should also be conducted for both day and night operations.

§ 23.1431 Electronic equipment

- (c) For airplanes required to have more than one flightcrew member, the cockpit must be evaluated to determine if the flightcrew members, when seated at their duty station, can converse without difficulty under the actual cockpit noise conditions when the airplane is being operated.
- (e) If provisions for the use of communication headsets are provided, it must be demonstrated that the flightcrew members will receive all aural warnings under the actual cockpit noise conditions when the airplane is being operated when any headset is being used.

Discussion: These evaluations need to be conducted to determine that communications between crew members can be adequately accomplished. Evaluations to determine compliance with this regulation are normally conducted during ground and flight tests under the highest expected noise conditions (e.g., high speed and full throttle). Crew members should be able to effectively communicate without excessive effort, e.g. shouting to be heard. It would be useful to analyze and identify potential noise sources early in the program.

All aural alerts need to be evaluated with and without headsets to assess their effectiveness and acceptability under all ambient noise conditions that may be encountered in the operational environment. There have been problems created by using active noise reduction headsets in older cockpits that have an alert sounded only in the cabin and not in the cockpit. The aircraft evaluations should also include the examination of an active noise reduction (ANR) system if it is going to be used on the airplane.

§ 23.1523 Minimum flight crew

The minimum flight crew must be established so that it is sufficient for safe operation, considering:

(a) Workload on individual crewmembers; in addition for commuter category airplanes, each crewmember workload determination must consider the following:

- (1) Flight path control;
- (2) Collision avoidance;
- (3) Navigation;
- (4) Communications;
- (5) Operation and monitoring of all essential airplane systems;
- (6) Command decisions; and

(7) The accessibility and ease of operation of necessary controls by the appropriate crewmember during normal and emergency operations when at the crewmember flight station.

(b) Accessibility and ease of operation of necessary controls by the appropriate crewmember; and

(c) Kinds of operation authorized under § 23.1525.

Discussion: The above rule addresses the minimum crew determination through the evaluation of individual workload. The rule differentiates the types of activities and areas that must be considered for commuter category airplanes (e.g., Navigation, Communication,

etc.), with no mention of the types of activities and areas that should be considered for other part 23 airplanes. Generally, these same types of activities and areas are applicable to normal operations for non-commuter category airplanes. Consequently, in practice, the areas and tasks listed under (a) have been applied to evaluations of non-commuter airplanes. In many cases, the minimum crew may be well established early in the project, before any evaluations of workload have been conducted. The minimum crew may be set by the design from the outset. This is not unusual as the airplane performance characteristics and cockpit configuration may well resemble other models that have been previously certified by the manufacturer. The process and level of evaluation for determining minimum crew determination for these situations will depend on the differences between already certified models and configurations, and the model or configuration seeking certification. A much more thorough evaluation will be needed for a new model than for a follow-on model or one that has minor modifications made to the cockpit. Regardless of the level of difference or modification, all new or modified systems or procedures, or both, should be evaluated for impact on crew complement and the pilot/system interface. For airplanes with an established crew complement, the purpose of this testing will be to corroborate by demonstration the predicted crew workload submitted by the applicant in order to substantiate compliance with § 23.1523. Testing is also to provide an independent and comprehensive assessment of individual crewmember workload in a realistic operating environment. It is recognized that any problems or issues identified with the system would most likely be resolved through design or procedural changes.

Workload should be assessed through a logical process of analysis, measurement and demonstration. One acceptable analytical approach assesses workload as a percentage of time available to perform tasks (time-line analysis). A frequently used basis for evaluating a new design is to compare performance and workload against a previously certified design that has been proven in operational service. However, if the new design represents a significant departure from the previous design, a comparative evaluation may not be appropriate. In this case, a stand-alone evaluation that collects objective and subjective data from subject pilots should be used. The FAA and U.S Air Force developed a report for certification use to assist in evaluation of pilot workload. This report, "Assessment of Crew Workload Measurement Methods, Techniques, and Procedures," Volume II (Report No. WRDC-TR-89-7006) provides guidance for selecting and using a number of subjective, physiological, and performance based workload measurement techniques.

An evaluation team is usually assembled when certified systems and the proposed system are significantly different. Such a team includes FAA test pilots, applicant test pilots and, if possible, "line pilots" who routinely fly similar airplanes. The testing should be conducted using scenarios representative of the type of operations for which the airplane will be used. Testing should include various types of routes, navigational aids, environmental conditions and traffic densities. Particular attention should be given to tasks that involve planning and execution of emergency and non-normal procedures. When appropriate, dispatch under the Master Minimum Equipment List (MMEL) should also be considered in combination with other failures that are likely to result in significantly increased pilot/crew workload. Since display format and media also influence workload, the number, size, location, type of display, and presentation format should also be part of the overall evaluation.

Discussion of crew complement and the associated crew workload between the involved FAA Aircraft Certification Office and the manufacturer should take place early in the development cycle. These discussions should focus on identification of design features that are likely to impact crew workload. These design features need to be evaluated to ensure that they do not place excessive workload demands on any crewmember. The applicant should submit a test plan describing the details of the evaluation approach. The Flight Test Guide for the Certification of Part 23 Airplanes (AC 23-8A) provides some excellent information for the conduct of the testing. Also, although developed for Transport Category airplanes AC 25.1523 contains useful information that may be used to address this rule.

§ 23.1555 Control markings

(a) Each cockpit control, other than primary flight controls and simple push button type switches, must be plainly marked as to its function and method of operation.

Discussion: The intent of this regulation is to ensure that pilots can quickly and unambiguously identify the function and understand the method of control operation. In conventional designs, the marking or labeling of controls was normally accomplished using text that describes the function of that control. With the advent of multifunction displays (mfd's) and integrated systems, there has now been an emerging trend to integrate control functions into these displays. Many of the traditional systems (e.g., fuel, power, electrical, warning/caution, etc.) are now being integrated into a single display along with their associated control function and corresponding labels. The operation of these systems is being accomplished via interaction with mfd controls (bezel switches, touch screens, etc.) and software control labels or icons that appear on the display screen. The design of these labels and their associated meanings need to be carefully evaluated to determine that they adequately convey and completely define the control function and system operation. Often, a single text message or acronym may not be sufficient to completely describe the function and operation of that control.

There has also been a growing trend to use icons rather than text on some of these displays. The symbol used can often be difficult to interpret or require training for the pilot to remember what it means or it may require the pilot to revert to a manual for interpretation; therefore, care must be taken to ensure that pilots will be able to identify control functions with an acceptable level of accuracy and consistency and in a timely manner. If icons are used, the level of pilot performance should not be reduced when compared with performance obtained using text labeling, and as measured using time to interpret and accuracy of interpretation of that control function.

There has also been a trend to use more multifunction controls (soft-keys) in airplanes. Pilots must be able to quickly and reliably identify the function being controlled by these software labels. The standard that should be applied is that pilots must be capable of performing control-related tasks to the same performance standards as would result from the use of conventional controls unless the decrement is inconsequential and the design enables other significant performance gains or design simplifications.

Control markings should be evaluated to ensure that a logical and consistent labeling convention has been applied throughout the cockpit. The evaluation should also consider

electronic control labeling, particularly as applied across all display pages. It is important that the terminology chosen for that control function is immediately and clearly understood by the expected pilot population. The evaluation should verify that the terms chosen conform to standardized aviation conventions. A list of standard terms and acronyms accepted by the FAA can be found in Appendix O of RTCA/DO-229C, November 28, 2001, “Minimum Operational Performance Standard for Global Positioning System/Wide Area Augmentation System Airborne Equipment.” This list has been included in Appendix F of this publication.

It is also important to have consistent function labels; a function should have the same name regardless of the display page on which it appears. Evaluations should be performed to determine that labels are consistently placed on the same key on the display when pages are changed. The evaluator should ensure that all identical functions that are available across multiple screens or pages are consistently mapped to the same control to the maximum extent possible. Failure to consistently position soft-key functions can increase the time required to search and find a given function and increase the likelihood of entry error. One must also assess whether frequently used functions are readily accessible. In most cases, it has been found that frequently used functions require a dedicated control to provide adequate accessibility.

All of the assessments should be conducted as early in the program as possible. In addition, these assessments should also include a sample of test pilots that are unfamiliar with the system. This can aid in the determination of the intuitiveness of labels and potential for misinterpretation.

APPENDIX B

Related Documents

1. GAMA PUBLICATION NO. 10, Recommended Practices and Guidelines for Part 23 Cockpit/Flight Deck Design.

This document was published September 2000 and is available for free download from GAMA (www.generalaviation.org). This document was developed cooperatively by industry and the FAA. The purpose of this document is to provide manufacturers of small aircraft and systems with current human factors recommendations for the design of cockpit or flight decks and their associated equipment to enhance overall aircraft safety.

This document should be useful to manufacturers in understanding human factors issues as they proceed through the design, development, and evaluation of their product.

2. Society of Aeronautical Engineers (SAE) Aerospace Recommended Practice 4033, “Pilot-System Integration,” August 1995.

This document provides a concept development guide to the human engineering specialist and the aircraft systems designer for pilot-system integration that will enhance safety, productivity, reduce certification risk, and improve cost effectiveness. It addresses the resulting processes of system development including aspects of interface design and automation philosophy. (SAE publications are available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001; telephone (412) 776-4970; or e-mail at publications@sae.org.)

3. The FAA and Industry Guide to Avionics Approvals, April 2001.

This document describes how to plan, manage, and document an effective, efficient avionics approval process and working relationship between the FAA and the applicant. This guide should be used by the FAA and applicants to obtain design, production, and installation approvals of avionics equipment.

The basic structure and premise of the processes described may be applied to non-avionics appliances as well. It should be noted, however, that depending on the type of product, the applicability will vary.

Appendix III of this document also provides human factors guidance as part of the product approval process.

4. The FAA and Industry Guide to Product Certification.

This purpose of this document is to provide a description of an improved certification process referred to as the Certification Process Improvement (CPI). This Guide describes how to plan, manage, and document an effective, efficient product certification process and working relationship between the FAA and applicants.

5. FAA Booklet, “The FAA Type Certification Process,” Aircraft Certification Service, May 1996.

The FAA’s Aircraft Certification Service issued this document for both internal use and industry guidance. It describes the important steps in the process leading to issuance of a type certificate. Discussion includes descriptions of roles, responsibilities, and job functions of participants in the process, and it provides a listing of the “best practices” that the FAA can follow to do its job well. It also describes the use of a Certification Plan as a key communication tool during the certification process.

**6. FAA Order 8110.4A, “Type Certification Process,” March 2, 1995;
and**

7. FAA Order 8110.5, “Aircraft Certification Directorate Procedures,” October 1, 1982.

These Orders prescribe the responsibilities and procedures for FAA aircraft certification engineering and manufacturing personnel when accomplishing the evaluation and approval of aircraft type design data and changes to approved type design data. These Orders contain descriptions of Certification Plans and how FAA personnel can use them during the certification process. These documents can be found on the Internet at:

<http://www.mmac.jccbi.gov>

and

<http://av-info.faa.gov>

8. Advisory Circular (AC) 21-40, “Application Guide for Obtaining a Supplemental Type Certificate,” May 6, 1998.

This advisory circular contains guidance for preparing a Certification Plan for a supplemental type certification project. Figure 2-4 of the AC suggests that applicants use a specific format for the plan and provides a sample of it, which includes the following sections:

1. Introduction
2. System description
3. Certification requirements
 - (a) Regulations
 - (b) Special requirements, unique or novel design aspects
 - (c) Compliance checklist
4. Methods of compliance

5. Functional hazard assessment summary
6. Operational considerations
7. Certification documentation
8. Certification schedule
9. Use of designees and identification of individual Designated Engineering Representatives (DER)/Designated Airworthiness Representatives (DAR)

These sections, and the material they contain, are appropriate for any applicant's Certification Plan. They also could be applied to the development of an HFCP. This document can be found on the Internet at <http://www.faa.gov>.

9. Human Force Exertions in Aircraft Control Locations, AMRL TR 71 119, Feb 1972.

This study was conducted to determine strength requirements to operate controls located in various positions in the cockpit from the pilot's seat. The study can be used to assist in determining strength considerations for control operations from various control positions in the cockpit.

10. ANM Policy Memos (1) Reviewing Human Factors Certification Plans. ANM 99-2, published 10/99 and (2) Human Factors Methods of Compliance, ANM01-03 published 5/01

These documents contain human factors guidance for the submittal of part 25 Certification Plans and Methods of Compliance. The information contained in these policy memos is similar to the content of the part 23 policy contained herein.

11. AC 23.1309-1C Equipment, Systems, and Installations in Part 23 Airplanes

This advisory circular provides guidance on equipment installations in part 23 airplanes in accordance with the requirements of 14 CFR part 23, § 23.1309.

12. AC 23.1311-1A Installation of Electronic Displays in Part 23 Airplanes

This advisory circular provides guidance on the installation of electronic displays for part 23 airplanes in accordance with the requirements of 14 CFR part 23, § 23.1311

13. SAE ARP 4102/7 Electronic Displays

This SAE document was primarily developed for Transport Category airplanes and older CRT technology; however, it still contains applicable guidance for display considerations including symbology considerations for flight displays, engine displays, alerting systems, etc. This information is contained in the Appendices A, B, and C of this document.

14. TSO C129 CLASS A, FAA Aircraft Certification Human Factors and Operations Checklist for Standalone GPS Receivers

This document contains human factors guidance in the form of a checklist to assist certification personnel to conduct evaluations of GPS systems.

APPENDIX C

Examples of Methods of Compliance

After the applicable regulations have been identified, the HFCP needs to describe the method that will be used to show compliance with each regulation. There are a variety of means that may be used by the applicant to show compliance. The table below lists 11 different methods that have been used by applicants.

Means of Compliance	Type of Compliance	Associated Compliance Documents
MC-1: Compliance Statement	Engineering Evaluation	Type Design Documents
- Reference to Type Design Documents		Recorded Statements
- Election of Methods and Factors		
MC-2: Design Review		Descriptions, Drawings
MC-3: Calculation/Analysis		Substantiation Reports
MC-4: Safety Assessment		Safety Analysis
MC-5: Laboratory Tests	Tests	Test Program
MC-6: Ground Tests on aircraft		Test Schedules
MC-7: Flight Tests		Test Reports
MC-8: Simulation		Test Interpretation
MC-9: Inspection	Inspection	Inspection Records
9.1 Design Inspection		
9.2 Conformity Inspection		
MC-10: Conformity Inspection		
MC-11: Equipment Qualification	Equipment Qualification	Equipment Qualification is a process which may include all previous means of compliance

Following is some supplemental information about the various types of compliance methods:

1. ENGINEERING EVALUATION

a. Drawings: Layout drawings or engineering drawings, or both, that show the geometric arrangement of hardware or display graphics.

b. Configuration Description: A description of the layout, arrangement, direction of movement, and so forth, or a reference to similar documentation.

c. Statement of Similarity: A description of the system to be approved and a previously approved system, which details their physical, logical, and operational similarities, with respect to compliance with the regulations. If the system is unchanged from a previously approved configuration as it relates to a specific 14 CFR section, that can be stated and previously approved documents can be cited.

d. Evaluations, Assessments, Analyses: Evaluations conducted by the applicant or others (not the FAA or a designee), who provides a report to the FAA. These include:

- Engineering Analyses: These assessments can involve a number of techniques, including such things as procedure evaluations (complexity, number of steps, nomenclature, and so forth); reach analysis via computer modeling; time-line analysis for assessing task demands and workload; or other methods, depending on the issue being considered.

- Mock-up Evaluations: These types of evaluations use physical mock-ups of the flight deck or components, or both. They are typically used for assessment of reach and clearance; thus, they demand a high degree of geometric accuracy.

- Part-Task Evaluations: These types of evaluations use devices that emulate (using flight hardware, simulated systems, or combinations) the crew interfaces for a single system or a related group of systems. Typically, these evaluations are limited by the extent to which acceptability may be affected by other flight deck tasks.

- Simulator Evaluations: These types of evaluations use devices that represent an integrated cockpit (using actual hardware, simulated systems, or combinations) and the operational environment. They also can be “flown,” with response characteristics that replicate, to some extent, the responses of the airplane. Typically, these evaluations are limited by the extent to which the simulation is a realistic, high fidelity representation of the airplane, the cockpit, the external environment, and crew operations.

In-Flight Evaluations: These evaluations use the actual airplane. Typically, these evaluations are limited by the extent to which the flight conditions of particular interest (for example, weather, failures, unusual attitudes) can be located or generated, or both, and then safely evaluated in flight.

e. Demonstrations: Similar to evaluations (described above), but conducted by the applicant with participation by the FAA or its designee. The applicant provides a report and requests FAA concurrence on the findings. Examples of demonstrations include:

- Mock-up Demonstration
- Part-Task Demonstration
- Simulator Demonstration

2. TESTS

f. Tests: Evaluations conducted by the FAA or a designee, which may encompass:

- Bench Tests: These are tests of components in a laboratory environment. This type of testing is usually confined to showing that the components perform as designed. Typical bench testing may include measuring physical characteristics (for example, forces, luminance, format) or logical or dynamic responses to inputs, either from the user or from other systems (real or simulated).

- Ground Tests: These are tests conducted in the actual airplane, while it is stationary on the ground. In some cases, specialized test equipment may be employed to allow the airplane systems to behave as though the airplane was airborne.

- Simulator Tests: (See simulator evaluations above.)

- Flight Tests: These are tests conducted in the actual airplane. The on-ground portions of the test (for example, preflight, engine start, taxi) are typically considered flight test rather than ground test.

The methods identified above cover a wide spectrum from documents that simply describe the product to partial approximations, and methods that replicate the actual airplane and its operation with great accuracy. Features of the product being certified and the types of human factors issues to be evaluated are key considerations when selecting which method is to be used. The characteristics described below can be used to help in coming to agreement regarding what constitutes the minimum acceptable method(s) of compliance for any individual requirement.

When a product needs to meet multiple requirements, some requirements may demand more complex testing while others can be handled using simple descriptive measures. It is important to note that the characteristics are only general principles. They are intended to form the basis for discussions regarding acceptable methods of compliance for a specific product with respect to a requirement.

3. Inspection

g. Inspection: A review by the FAA or its designee, who will be making the compliance finding.

APPENDIX D

Sample Human Factors Compliance Matrix

	<div style="display: flex; justify-content: space-around; padding: 5px;"> <div style="transform: rotate(-45deg); transform-origin: center;">Design Review</div> <div style="transform: rotate(-45deg); transform-origin: center;">Analysis</div> <div style="transform: rotate(-45deg); transform-origin: center;">Mock-up/Bench Test</div> <div style="transform: rotate(-45deg); transform-origin: center;">Simulation</div> <div style="transform: rotate(-45deg); transform-origin: center;">Ground Test</div> <div style="transform: rotate(-45deg); transform-origin: center;">Flight Test</div> </div>						
Regulatory Requirement							Compliance Documentation
§ 23.771(a) – Each pilot compartment and its equipment must allow the minimum flightcrew to perform their duties without unreasonable concentration or fatigue.			√			√	Report No. G60-002
§ 23.777(b) – The controls must be located and arranged so that the pilot, when seated, has full and unrestricted movement of each control without interference from either pilot's clothing or the cockpit structure.			√		√		Report No. G60-004
§ 23.777(e) – Identical powerplant controls for each engine must be located to prevent confusion as to the engines they control.	√			√		√	Report No. G60-004
§ 23.1309(b)(3) – Warning information must be provided to alert the crew to unsafe systems operating conditions and to enable to them to take appropriate corrective action. Systems, controls, and associated monitoring and warning means must be designed to minimize crew errors that could create additional hazards.	√	√		√		√	Report No. G60-012
§ 23.1381(a)-The instrument lights must...Make each instrument and control easily readable and discernible.					√	√	Report No. G60-010
§ 23.1381(b)-The instrument lights must...Be installed so that their direct rays, and rays reflected from the windshield or other surface, are shielded from the pilot's eyes.					√	√	Report No. G60-010

APPENDIX E
Checklist for Reviewing Human Factors Certification Plans

	YES	NO	NA
1. Introduction			
2. System Description			
a. Intended Function			
b. Cockpit or Flight Deck Layout			
c. Underlying principles for crew procedures			
3. Concept of Operation considerations			
a. Pilot characteristics			
b. Operational considerations System			
Operation Procedures			
c. Training requirements			
4. Certification requirements			
a. HF related Regulations			
5. Methods of compliance			
6. System Safety Assessment			
7. Certification Documentation			
8. Certification Schedule			
a. HFCP Certification Plan Submittals			
b. Cockpit or Flight Deck Reviews, Early Prototype Reviews, Simulator Reviews, Flight Deck Demonstrations			
c. Coordination Meetings			
9. Use of Designees and Identification of Individual DER'S			

APPENDIX F - GLOSSARY AND ACRONYMS

AC – Advisory Circular

ACARS -Aircraft Communications Addressing and Reporting System

Active Waypoint -A waypoint to or from which navigational guidance is being provided. For a parallel offset, the active waypoint may or may not be at the same geographical position as the parent waypoint. When not in the parallel offset mode (operating on the parent route), the active and parent waypoints are at the same geographical position.

ADS -Automatic Dependent Surveillance

ADS-B -Automatic Dependant Surveillance-Broadcast

Advisory -An annunciation that is generated when crew awareness is required and subsequent crew action may be required; the associated color is unique but not red or amber/yellow- (Source: Advisory Circular AC 25-11).

AGL -Above Ground Level

AIP -Aviation Information Publications

Along-Track Distance -The distance along the desired track from the waypoint to the perpendicular line from the desired track to the aircraft.

Applications -Specific use of systems that address particular user requirements. For the case of GNSS, applications are defined in terms of specific operational scenarios.

APV -Approach operations with Vertical guidance (The terminology CAT -I PA, APV - II, and APV -I has been introduced to describe the three levels of SBAS precision approach service and is consistent with the ICAO GNSS ANNEX 10 SARPs. The FAA plans to label CAT-I PA as "GNSS Landing System (GLS)" and APV-I as "LNAV/VNAV". The naming convention for APV-II has not been proposed.)

Area Navigation (RNAV) -Application of the navigation process providing the capability to establish and maintain a flight path on any arbitrary chosen course that remains within the coverage area of navigation sources being used. RNAV utilizing capabilities in the horizontal plane only is called 2D RNAV, while RNAV that also incorporates vertical guidance is called 3D RNAV. Time navigation (TNAV) may be added to either 2D or 3D systems. TNAV added to a 3D system is called 4D.

ARINC -Aeronautical Radio

ASIC -Application Specific Integrated Circuit

ATC -Air Traffic Control

Availability -The availability of a navigation system is the ability of the system to provide the required function and performance at the initiation of the intended operation. Availability is an indication of the ability of the system to provide usable service within the specified coverage area. Signal availability is the percentage of time that navigational signals transmitted from external sources are available for use. Availability is a function of both the physical characteristics of the environment and the technical capabilities of the transmitter facilities.

Barometric Altitude -Geopotential altitude in the earth's atmosphere above mean standard sea level pressure datum surface, measured by a pressure (barometric) altimeter.

BCD -Binary Coded Decimal

BER - Bit Error Rate

BNR – Binary Numbers

BPSK -Binary Phase Shift Keying

BW -Bandwidth

C/A -Coarse Acquisition

CAT-I PA -Category I Precision Approach

Caution -An annunciation that is generated when immediate crew awareness is required and subsequent crew action will be required; the associated color is amber/yellow. (Source: Advisory Circular AC25 -11)

CC -Clock Correction

CDI -Course Deviation Indicator

Center of Navigation -The mathematical point, referenced to the aircraft coordinate frame, associated with the GNSS navigation solution. This point would typically be the phase center of the GNSS antenna, but could also be an offset or translated point (e.g., might be translated vertically to the level of the wheels of a large aircraft).

CF -Course-to-Fix

CFIT -Controlled Flight Into Terrain

Continuity -The continuity of a system is the ability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without interruption during the intended operation. More specifically,

continuity is the probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation, and predicted to exist throughout the operation.

Coverage -The coverage provided by a radio navigation system is that surface area or space volume in which the signals are adequate to permit the user to determine position to a specified level of accuracy. Coverage is influenced by system geometry, signal power levels, receiver sensitivity, atmospheric noise conditions and other factors that affect signal availability.

CRC -Cyclic Redundancy Check

CW -Continuous Wave

CWI -Continuous Wave Interference

DCH -Datum Crossing Height

DD -Double Delta

DDL -Delay Lock Loop

DESIRED COURSE

a. True -A predetermined desired course direction to be followed (measured in degrees from true north).

b. Magnetic -A predetermined desired course direction to be followed (measured in degrees from local magnetic north).

Desired Track -The planned or intended track between two waypoints. It is measured in degrees from either magnetic or true north. The instantaneous angle may change from point to point along the great circle track between waypoints.

DME -Distance Measuring Equipment

DOD -U.S. Department of Defense

DOP - Dilution of Precision

DP -Datum Point

D.R.- Dead Reckoning

EC – Ephemeris CORRECTION

ECEF -Earth Centered Earth Fixed

EFIS -Electronic Flight Instruments System

EGNOS -European Geostationary Navigation Overlay Service

EL – Glide Path Angle (approach path elevation angle)

E-L – Early minus Late (correlator)

ELT -Emergency Locating Transmitter

En Route -A phase of navigation covering operations between departure and termination phases. En route phase of navigation has two subcategories: en route domestic/continental and en route oceanic.

FAA -Federal Aviation Administration

FAF -Final Approach Fix

FAS -Final Approach Segment

FAWP -Final Approach Waypoint

FD -Fault Detection

FDE -Fault Detection and Exclusion

FEC -Forward Error Correction

Final Approach Fix (FAF) -A point in space used to indicate the position at which an aircraft on a standard approach should be stabilized with appropriate guidance being supplied for the Final Approach Segment. (Source: FAA)

Final Approach Segment (FAS) -The straight-line segment which prescribes the three-dimensional geometric path in space that an aircraft is supposed to fly on final approach. This segment is defined by two points in space, the Glide Path Intercept Waypoint (GPIWP) and the Threshold Crossing Waypoint (TCWP).

Flight Technical Error (FTE) -The accuracy with which the aircraft is controlled as measured by the indicated aircraft position with respect to the indicated command or desired position. It does not include blunder errors.

FMS – Flight Management System

FPAP – Flight Path Alignment Point

FSD- Full Scale Deflection

FTE -Flight Technical Error

GARP -GNSS Azimuth Reference Point

GDOP -Geometric Dilution of Precision

GEO -Geostationary

Geocentric -Relative to the earth as a center, measured from the center of the earth.

Geodesy -The science related to the determination of the size and shape of the earth (geoid) by such direct measurements as triangulation, leveling and gravimetric observations; which determines the external gravitational field of the earth and, to a limited degree, the internal structure.

Geometric Dilution of Position (GDOP) -The ratio of position error of a multilateration system. More precisely, it is the ratio of the standard deviation of the position error to the standard deviation of the measurement errors, assuming all measurement errors are statistically independent and have a zero mean and the same standard distribution. GDOP is the measure of the "goodness" of the geometry of the multilateration sources as seen by the observer; a low GDOP is desirable, a high GDOP undesirable. (See also PDOP, HDOP and VDOP.)

Geostationary -An equatorial satellite orbit that results in a constant fixed position of the satellite over a particular earth surface reference point. (GPS and GLONASS satellites are not geostationary)

GIVE -Grid Ionospheric Vertical Error

GIVEI -Grid Ionospheric Vertical Error Indicator

GL -Ground Level

GLS -GNSS Landing System

Global Navigation Satellite System (GNSS) -GNSS is a world-wide position, velocity, and time determination system, that includes one or more satellite constellations, receivers, and system integrity monitoring, augmented as necessary to support the required navigation performance for the actual phase of operation.

GPIP -Glide Path Intercept Point

Global Positioning System (GPS) -A space-based positioning, velocity and time system composed of space, control and user segments. The space segment, when fully operational, will be composed of 24 satellites in six orbital planes. The control segment

consists of five monitor stations, three ground antennas and a master control station. The user segment consists of antennas and receiver-processors that provide positioning, velocity, and precise timing to the user.

GLONASS -Global Orbiting Navigation Satellite System

GNSS -Global Navigation Satellite System

GNSSU -GNSS (Landing) Unit

GPS -Global Positioning System

HAL -Horizontal Alert Limit

HAT -Height Above Touchdown

HDOP – Horizontal Dilution of Position

Height Above Touchdown (HAT) – Specifically, the height above the Runway Intercept Waypoint. In using this term for airborne equipment specifications, care should be taken to define the point on the aircraft (GPS antenna, wheel height, center of mass) that applies.

HF – High Frequency

HIRF – High Intensity Radiation Fields

Horizontal Dilution of Precision (HDOP) – The ratio of user-referenced horizontal position error to measurement error of a multilateration system. (See GDOP for a more detailed description.)

HOW – Hand Over Word

HPL – Horizontal Protection Level

HSI – Horizontal Situation Indicator

HUL – Horizontal Uncertainty Level

Hz -Hertz (cycles per second)

IAPW -Initial Approach Waypoint

I C -Ionospheric Correction

ICAO -International Civil Aviation Organization

ID -Identification

IFR -Instrument Flight Rules

IGP -Ionospheric Grid Point

ILS -Instrument Landing System

IMC -Instrument Meteorological Conditions

INS -Inertial Navigation System

IOD -Issue of Data

IODC -Issue of Data Clock

IODE -Issue of Data Ephemeris

IODF -Issue of Data Fast Correction

IODI -Issue of Data Ionospheric

IODP -Issue of Data PRN mask

IODS -Service Issue of Data

IPP -Ionospheric Pierce Point

IPV -Instrument Procedures with Vertical guidance

I/S -interference-to-signal ratio

IWP -Intermediate Waypoint

LI-1575.42 MHz

LAAS -Local Area Augmentation System

LNAV -Lateral Navigation

LORAN -Long Range Navigation

LSB -Least Significant Bit

LSR -Least Squares Residual

LTP/FTP -Landing Threshold Point/Fictitious Threshold Point

m -Meters

MAHWP -Missed Approach Holding Waypoint

Mask Angle -A fixed elevation angle referenced to the user's horizon below which satellites are ignored by the receiver software. Mask angles are used primarily in the analysis of GNSS performance, and are employed in some receiver designs. The mask angle is driven by the receiver antenna characteristics, the strength of the transmitted signal at low elevations, receiver sensitivity and acceptable low elevation errors.

MASPS -Minimum Aviation System Performance Standards

MDA -Minimum Descent Altitude

MAWP –Missed Approach Waypoint

Mcps -Mega-chips/second

Misleading Information -Within this standard misleading information is defined to be any data which is output to other equipment or displayed to the pilot that has an error larger than the current protection level (HPL/VPL). This includes all output data, such as position, non-numeric cross-track, numeric cross- track, and distance-to-waypoint as applicable.

MLS -Microwave Landing System

MOPS -Minimum Operational Performance Standards

MSAS -MTSAT Satellite-based Augmentation System

MSL -Mean Sea Level

MT -Message Type

MTBF -Mean Time Between Failure

MTSAT -Multifunction Transport Satellite

NAD-83 -North American Datum 1983

NAS -U.S. National Airspace System

NAV -Navigation

NAVAID -Navigation Aid

Navigation Mode -The navigation mode refers to the equipment operating to meet the requirements for a specific phase of flight. The navigation modes are: oceanic/remote, en route, terminal, non-precision approach, and precision approach. The oceanic/remote mode is optional; if it is not provided, the en route mode can be substituted for the oceanic mode.

NDB -Non-Directional Beacon

NIS -Number of Independent Samples

NM -Nautical Mile

Non Precision Approach -A standard instrument approach procedure in which no glide slope/glide path is provided. (Source: FAA document 711O.65G)

NPA- Non Precision Approach

NSE -Navigation System Error

OBS -Omni Bearing Selector

PA -Precision Approach

PDOP -Position Dilution of precision

Planned Primary Means of Navigation -Planned primary means of navigation refers to the capability of planning an operation around scheduled outages so that the system is available for a particular flight and the operational continuity, integrity and accuracy requirements are met.

Position Dilution of Precision (PDOP) -The ratio of user-referenced three-dimensional position error to measurement error of a multilateration system, PDOP is the root-gum-square of HDOP and VDOP.

Position Fix -A derived location of an entity' in a common coordinate system.

Position Fixing Error – The accuracy with which a navigation sensor in combination with a navigation computer can calculate and provide an output of actual location in relation to desired location in an operational environment.

PPOS -Present Position

PR -Pseudo Range

PRC -Pseudo Range Correction

Precision Approach (PA) -A standard instrument approach procedure in which a glide slope/glide path is provided. (Source: FAA document 7110.65G)

PRN -Pseudo Random Noise

Pseudorange -The distance from the user to a satellite plus an unknown user clock offset distance. With four satellite signals it is possible to compute position and offset distance. If the user clock offset is known, three satellite signals would suffice to compute a position.

Radio navigation -The determination of position, or the obtaining of information relating to position, for the purposes of navigation by means of the propagation properties of radio waves.

RAIM -Receiver Autonomous Integrity Monitoring

RDP -Runway Datum Point

Receiver Autonomous Integrity Monitoring (RAIM) – A technique whereby a civil GNSS receiver/processor determines the integrity of the GNSS navigation signals without reference to sensors or non-DOD integrity systems other than the receive itself. This determination is achieved by a consistency check among redundant pseudorange measurements.

Reliability – The probability of performing a specified function without failure under given conditions for a specified period of time.

Required Navigation Performance (RNP) – A measure of the navigation system performance within a defined airspace, route, or procedure, including the operating parameters of the navigation systems used within that airspace. (Source: Adapted from the ICAO Separation Panel).

RF -Radio Frequency

RF -Radius-turn-to-Fix

RGCS -Review of General Concepts of Separation Panel

RMI -Radio Magnetic Indicator

RNAV -Area Navigation

RNP -Required Navigation Performance

RRC -Range Rate Correction

rss -Root-Sum-Square

RTCA – RTCA, Inc. (publishes documents with the RTCA designator)

s – Second

SA – Selective Availability (also written as S/A)

SAE – Standard Aerospace Equipment

SATCOM – Satellite Communications

SBAS -Satellite Based Augmentation System (SBAS) -International name used in the Global Navigation Satellite System Panel (GNSSP) Standards and Recommended Practices (SARPs) for a set of programs that use satellites to transmit GPS and GLONASS integrity and correction data. The U.S. program is the WAAS that currently is planned to provide integrity and corrections to GPS and SBAS satellites only.

Selective Availability (S/A) -A set of techniques for denying the full accuracy and selecting the level of positioning, velocity, and time accuracy of GPS available to users of the Standard Positioning Service (L 1 frequency) signal.

SC -Special Committee (RTCA Special Committees)

SNR -Signal to Noise Ratio

SPS -Standard Positioning Service

sps -symbols per second

Standard Positioning Service (SPS) -The standard specified level of positioning, velocity and timing accuracy that is available, without qualifications or restrictions, to any user on a continuous worldwide basis.

STAR -Standard Terminal Arrival Routes

SV -Satellite Vehicle

TC -Tropospheric Correction

TCAS -Traffic Alert and Collision Avoidance System

TCH -Threshold Crossing Height

TCP -Threshold Crossing Point

Terminal Area -A general term used to describe airspace in which approach control service or airport traffic control service is provided.

TERPS -Terminal Instrument Procedures

TF -To-From

Threshold Crossing Height (TCH) -The height of the straight-line extension of the glide path above the runway at the threshold.

TOD -Time of Day: Top of Descent

Total System Error (TSE) – Generic: The root-sum-square of the navigation source error, airborne component error, display, and flight technical error. Specific: The root-sum-square of the position fixing error, display error, course selection error and flight technical error.

TOW – Time of Week

Track Angle – Instantaneous angle measured from either true or magnetic north to the aircraft's track.

TSE – Total System Error

TSO – Technical Standards Order

TTS – Time to Alert

TTFF – Time to First valid position Fix

UDRE – User Differential Range Error

UDREI – User Differential Range Error Indicator

UERE – User Equivalent Range Error

UIVE -User Ionospheric Vertical Error

URA -User Range Accuracy

User Range Accuracy (URA) -The one-sigma estimate of user range errors in the navigation data for each individual satellite. It includes all errors for which the space or control segment is responsible. It does not include any errors introduced at the user set.

UTC -Universal Time Coordinated

VAL -Vertical Alert Limit

VDOP -Vertical Dilution of Position

Vertical Dilution of Precision (VDOP) -The ratio of user-referenced vertical position error to measurement error of a multilateration system (see GDOP for a more detailed description).

Vertical Navigation (VNAV) -A function of RNAV equipment which calculates, displays and provides guidance to a vertical profile or path.

Vertical Profile -A line or curve, or series of connected lines and/or curves in the vertical plane, defining an ascending or descending flight path either emanating from or terminating at a specified waypoint and altitude, or connecting two or more specified waypoints and altitudes. In this sense, a curve may be defined by performance of the airplane relative to the airmass.

VFR -Visual Flight Rules

VHF -Very High Frequency

VNAV – Vertical Navigation

VOR -VHF Omni Range

VORTAC -VHF Omni Range / Tactical Air Navigation

VPL -Vertical Protection Level

VTF -Vector-to-Final (Approach)

VUL -Vertical Uncertainty Level

WAAS -Wide Area Augmentation System

Warning -An annunciation that is generated when immediate recognition and corrective or compensatory action is required; the associated color is red. (Source: Advisory Circular AC25 -11)

WGS- 72 -World Geodetic System 1972

WGS-84 -World Geodetic System 1984

WMS -Wide-area Master Stations (WAAS)

WN -Week Number

WNT -WAAS Network Time

World Geodetic Survey (WGS) -A consistent set of parameters describing the size and shape of the earth, the positions of a network of points with respect to the center of mass of the earth, transformations from major geodetic datums, and the potential of the earth (usually in terms of harmonic coefficients).

WPT -Waypoint

WRS -Wide-area Reference Stations (WAAS)

Distribution:

Manager, Transport Airplane Directorate, ANM-100
Manager, Rotorcraft Directorate, ASW-100
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